

State of the Tibetan lithosphere

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Although it has long been accepted that the uplift of the Himalaya and Tibet result from the collision of India with Eurasia, there is still no agreement on the details of the geodynamical processes involved. This lack of consensus arises primarily from uncertainties in the Tibetan upper mantle structure. The prevalent, but not universally accepted explanation has been that the uplift of Tibet was associated with delamination of at least part of the Tibetan lithosphere. We use a variety of seismic observations to assess the state of the Tibetan upper mantle. Waveform inversion of more than 50,000 low frequency multi-mode surface waveforms recorded in Asia for paths crossing the plateau show the existence of a high velocity lid extending at depths of 150-250 km across the entire plateau. At shallow depths (~130 km or less) the mantle velocity is slow beneath northern Tibet but fast beneath southern Tibet. However, the low-frequency surface waves have a lateral resolution of about 400 km.

We have analyzed a number of other seismic data which better resolve the structure of the Tibet crust and uppermost mantle. We have measured shorter-period (10-70 s) fundamental-mode Rayleigh-wave group-velocity dispersion for more than 4000 paths recorded in Tibet and India. The dispersion data are inverted with receiver-function data for lateral Vs variations of the crust and uppermost mantle. The interesting feature of this result is that while the sub-Moho mantle beneath southern and western Tibet is fast, that below central and northeastern Tibetan Plateau is slow at shallow depths (<125 km) but fast at deeper depths. In addition, fundamental mode Rayleigh wave phase velocities for paths confined to the northern part of the plateau are only 1-2 % slow in the 70-120 s period range compared to paths confined to the southern part of the plateau. These surface-wave observations from measurements largely confined to the plateau have higher resolution than the large-scale low-frequency surface-wave analysis but support the low-frequency surface-wave tomographic model.

Other seismic observations support this picture. Analysis of frequency-dependent Sn propagation in Tibet shows that at high frequency (~1 Hz) Sn is blocked for paths across the northern plateau but not for paths confined to the southern part of the plateau, a feature first noted more than 25 years ago. In contrast, low frequency (~0.2 Hz) Sn is observed to propagate across the whole of the plateau, consistent with the surface-wave results. Relative teleseismic S-wave delays measured for sites in the northern part of Tibet are delayed 0.5-1.0 s with respect to sites in southern Tibet. The magnitudes of the teleseismic S-wave delays are incompatible with complete removal of the Tibetan high-velocity lid and lithosphere.

These seismic observations indicate that the Tibetan high-velocity lid and lithosphere are still largely, if not completely intact. The seismic model suggests that most of the plateau has been underthrust by high wave speed Indian mantle from the south and possibly to a lesser extent, high wave speed Asian mantle from the north. Low velocities in the upper mantle beneath northern Tibet have previously been noted and these, along with the recent volcanism in northern Tibet, have been cited as evidence for lithospheric delamination beneath the plateau. However, the seismic studies reported here suggest that the low wave speeds in the upper mantle below central and northeast Tibet are a relatively a shallow feature and not the result of lithospheric delamination. We propose that the low velocity sub-Moho mantle beneath central and northeast Tibet result from radioactive heating of the thickened Tibetan crust. With increasing time, this heating results in a temperature inversion which heats the uppermost mantle lowering the sub-Moho shear velocity.

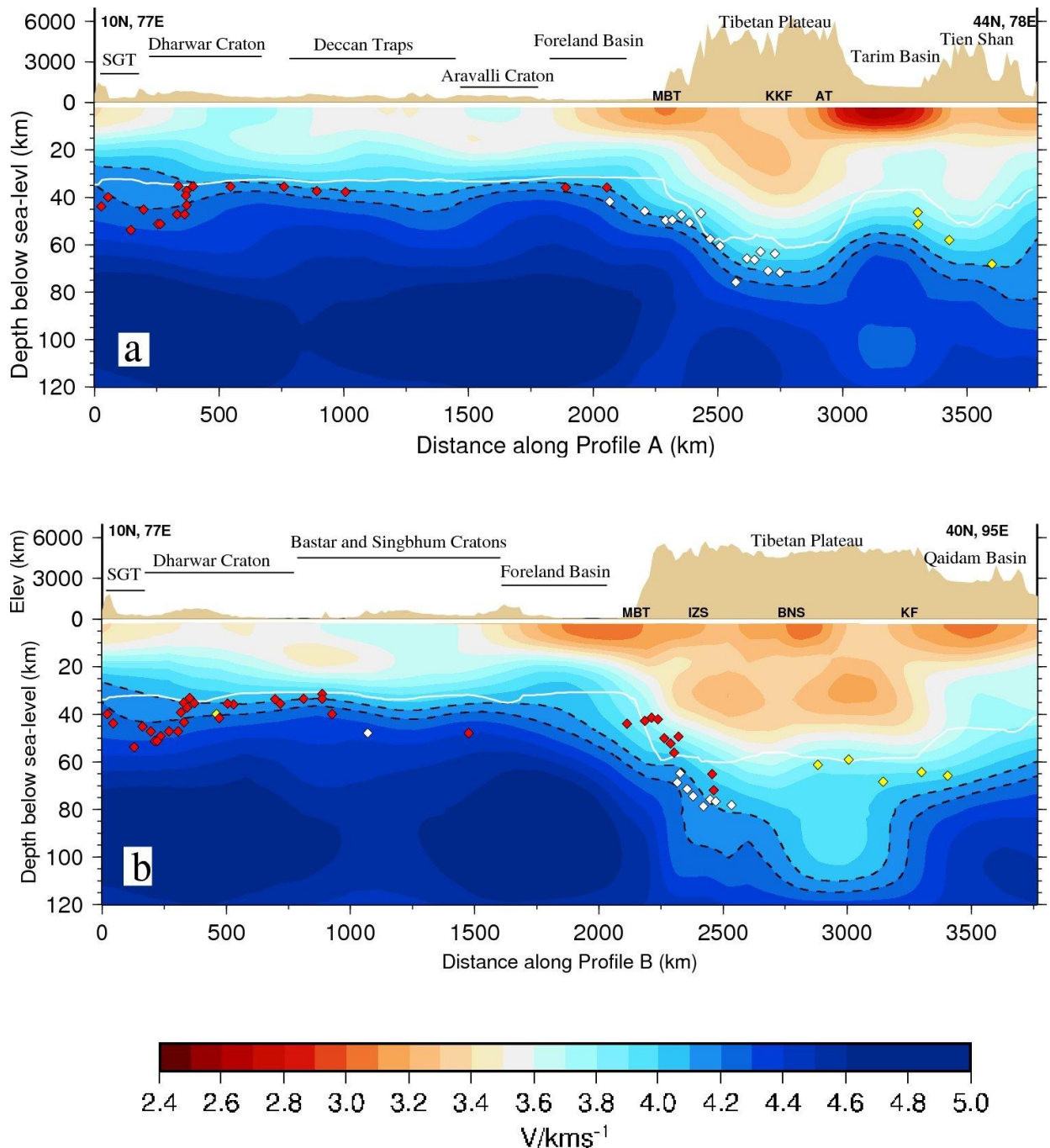


Figure 1. Velocity section through the Sv wave-speed model derived from inversion of the fundamental-mode Rayleigh-wave group-velocity data with receiver-function Moho depths superimposed. Profile (a) crosses India and western Tibet and profile (b) crosses India and eastern Tibet. The surface waves are sensitive to the crustal structure but because of their depth-averaging properties and frequency, are not sensitive to the details of the Moho discontinuity. Comparison of the surface-wave velocity model and the receiver-function results show the depth of the 4.1 km/s contour in the surface-wave model correlates, with a few exceptions, to the receiver-function Moho position for most of the Tibet-Indian region. Low sub-Moho shear velocities occur in the uppermost mantle beneath northeastern Tibet but not western Tibet.